CHELIDONOCEPHALUS TRILOBITE FAUNA
FROM THE CAMBRIAN OF IRAN

By R. A. FORTEY & A. W. A. RUSHTON

ABSTRACT

A trilobite assemblage from the Mila Formation in northern Iran contains *Chelidonocephalus preannulatus* sp. nov., *Hadragnostus edax* sp. nov., *Koldiniella mitella* Sivov, *Peronopsis fallax* aff. *minor* (Brögger), *Dorypyge* sp., *Parakoldinia* ? sp. and *Tsinania* ? sp. It is of earliest Upper Cambrian age. The type species of *Chelidonocephalus* King (*C. alifrons*) and *Iranoleesia* King (*I. pisiformis*) are redescribed ; *Iranoleesia falconi* (King) is transferred to *Anomocarella*. Some problems in the classification of ptychoparioid trilobites are discussed.

INTRODUCTION

In northern Iran Cambrian rocks crop out in the east–west trending Alborz Mountain belt south of the Caspian Sea. In western Iran further Cambrian outcrops are known along a belt parallel to the Zagros Thrust north-west of Shiraz (Fig. 12). Fossils from the latter area have been described by King (1937), and more recently Kushan (1973) described the faunas and zones of the Mila Formation (Stöcklin *et al*. 1964 : 20) in the Alborz Mountains.

While surveying the Qazvin quadrangle north-west of Tehran (Annells *et al*. 1975), Dr R. G. Davies collected fossiliferous samples from within *c*. 10 m of the local base of the Mila Formation near Sanghabad (field locality RD 569), at lat. 36° 06′ 43″ N, long. 50° 37′ 37″ E. These samples yielded an assemblage of trilobites somewhat ambiguous in age when compared with the faunas described by Kushan (1973). The assemblage includes well-preserved agnostids previously undescribed from Iran, and as a new species of *Chelidonocephalus* is present we have taken the opportunity to reassess *Chelidonocephalus* and associated genera and species known only from Iran, the affinities of which were obscure.

The trilobites are preserved, with fragments of horny brachiopods, in a grey sparry limestone cut by many minor joints. Several, but not all, show slight tectonic deformation. Although generally well preserved, the trilobites are all disarticulated and many were broken before fossilization.

Reference is made to specimens in the Palaeontology Department, British Museum (Natural History) (It and In), the Geological Survey of India (GSI) and the Institute of Geological Sciences, London.
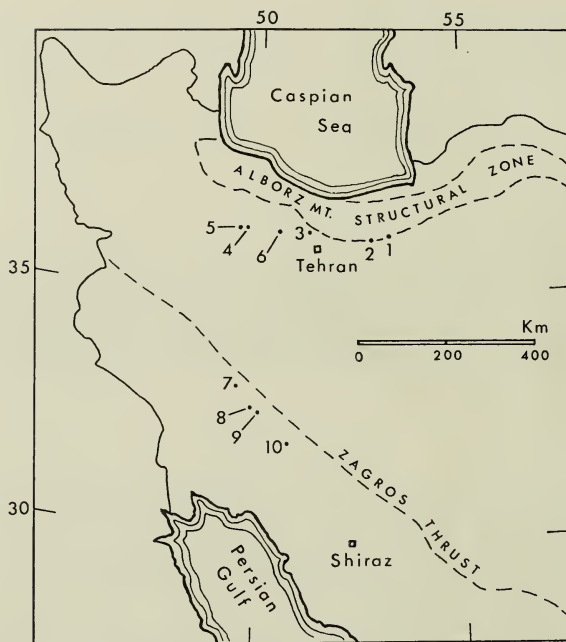
FIG. 12. Sketch-map of part of Iran. Structural lines from Stöcklin, 1968. Localities 1–5 are from Kushan 1973 : 1 = Mila Kuh, 2 = Shahmirzad, 3 = Haanakdar, 4 = Abhar, 5 = Qanli-Chapoghlu. Locality 6 = Sanghabad (R. G. Davies field Locality 569). Localities 7–10 are from King, 1937 : 7 = Chal-i-Sheh, 8 = Darreh Shu, 9 = Tang-i-Tehbud Bezuft, 10 = Ma'dan. *Chelidonocephalus alifrons* is recorded from localities 1, 3, 4, 5, 7, 8, 9, *Iranoleesia pisiformis* from 1, 3, 4, 5, 10 and *Koldiniella mitella* from 3, 4, 5, 6.

AGE AND CORRELATION OF THE FAUNA

Kushan (1973 : 125) recognized the following zones in the Mila Formation.

Tremadoc	*Saukia* Zone
Upper Cambrian	*Alborsella* Zone
	Kaolishania Zone
	Prochuangia Zone
	Drepanura Zone
Middle Cambrian	*Dorypyge* Zone
	Iranoleesia Zone

Iranoleesia is confined to its zone and is accompanied by *Anomocarella* etc. According to Kushan the several *Dorypyge* species are confined to the *Dorypyge* Zone and some are associated with agnostids and *Chelidonocephalus alifrons* or *C*. sp. The *Drepanura* Zone is characterized by *Drepanura* (*Spinopanura*) or by *Koldiniella*,

or both, and also contains *C. alifrons*, *C.* sp. and agnostids. Kushan did not allow for an overlap of the ranges of *Dorypyge* and *Koldiniella*, such as occurs in the present assemblage.

We refer the present fauna to the *Drepanura* Zone because there are several specimens of *Koldiniella mitella* in the collection, and the presence of this species, of agnostids and of a species of *Chelidonocephalus* are typical of this zone. There is, on the other hand, only one specimen of *Dorypyge* and that is a different species from any recorded by Kushan from the *Dorypyge* Zone. On *a priori* grounds Kushan made a good case for the Middle Cambrian age of the *Dorypyge* Zone and the Upper Cambrian age of the *Drepanura* Zone, but as the new record implies an Upper Cambrian age for a *Dorypyge* species (a genus hitherto restricted to the Middle Cambrian) we here examine the age of the fauna in relation to the Middle–Upper Cambrian boundary. We accept the boundary as being between the *Lejopyge laevigata* Zone and the *Agnostus pisiformis* Zone, as reviewed by Daily & Jago (1975). *Chelidonocephalus* is restricted geographically and is of no help in wider correlation, nor is the *Tsinania* ? sp. because it cannot be convincingly compared with other described forms. *Peronopsis fallax* aff. *minor* resembles a subspecies known from the late Middle Cambrian of Scandinavia and *P. fallax* cf. *minor* from the *A. pisiformis* Zone in the Nuneaton district, England (Taylor & Rushton 1972 : 19). *Hadragnostus edax* sp. nov. is comparable with *H. las* Öpik from the *eretes* and *quasivespa* Zones of the Mindyallan Stage in Queensland : Öpik regarded these horizons as Upper Cambrian but Daily & Jago (1975 : 538) suggested that the *eretes* Zone and part of the *quasivespa* Zone should be correlated with the top of the *laevigata* Zone, thus making *H. las* a topmost Middle Cambrian species. A third species, *Hadragnostus modestus* (Lochman), occurs in the *Crepicephalus* Zone of Montana (Lochman 1944) in beds equivalent to part of the *A. pisiformis* Zone. Thus these agnostids do not give a precise age as they are related to forms occurring both above and below the Middle–Upper Cambrian boundary.

The only species of the present fauna found beyond the Mila Formation is *Koldiniella mitella* Sivov, which occurs in the lowest Upper Cambrian at Salair, western Siberia. Rozova (1968 : table 4) correlated this occurrence with the Kulyumbe 'superhorizon' of north-eastern Siberia which is referable to the *Pedinocephalina–Toxotis* (?) Zone, and this in turn was correlated with a level above the base of the *A. pisiformis* Zone by Daily & Jago (1975 : 546). *K. mitella* seems therefore to indicate an Upper Cambrian age, and with it goes the rest of the fauna, including the *Dorypyge* sp. We furthermore conclude that Kushan's choice of the Middle–Upper Cambrian boundary in the Mila Formation was apposite.

SYSTEMATIC DESCRIPTIONS

CLASSIFICATION PROBLEMS. One of the reasons palaeontologists find the mass of 'ptychoparioid' trilobites difficult to classify is that some persist in forcing genera into higher taxonomic groups on the basis of a single character in defiance of other characters which contradict such an assignment. Blindness and effacement of external features are thought to have been polyphyletically derived. Yet the blind

Conocoryphidae even now have the company of such distinct genera as *Hartshillia* and *Meneviella* thrust upon them despite Lake's observations that this ignores the characters of their thoraces and pygidia (1940 : 277). Similarly, Kobayashi, who recognized the polyphyletic character of effaced trilobites (1935 : 303), grouped nine varied genera in the Tsinaniidae (1960 : 397) but he himself regarded five of these as doubtful, with which we agree. We would add a sixth, *Koldinia*. This leaves the family with three closely related genera – *Tsinania*, *Dictyites* and perhaps the poorly known *Dictyella* : if Kobayashi is correct in regarding all these as effaced asaphiscids is there any need for a family Tsinaniidae at all?

We have considered the genera likely to be related to *Chelidonocephalus*, *Iranoleesia* and *Anomocarella* below without regard to the (apparently haphazard) arrangement of the families in which they have been included. This has not led to a satisfactory understanding of the families concerned, and we have therefore been forced to use the category 'family uncertain'.

Family **AGNOSTIDAE** McCoy 1849
Genus *HADRAGNOSTUS* Öpik 1967

TYPE SPECIES. Original designation, *H. las* Öpik 1967.

DISCUSSION. *Hadragnostus* has a distinctive cephalon with a long glabella and short preglabellar field. The front of the cephalon is transverse and straight, or even slightly emarginate in *H. las* (Öpik 1967 : pl. 58, fig. 7) and *H. modestus* (Lochman 1944 : pl. 5, fig. 10) ; the new species *H. edax*, described below, has a straight or convex anterior margin.

The pygidium of *Hadrognastus* differs from that of *Peronopsis* in that it has a terminal node. *Baltagnostus* has a terminal node but the pygidial border between the posterolateral spines is widened medially (i.e. slightly crescent-shaped) or has a pygidial 'collar'. Öpik (1967 : 103) described the articulating device of *H. las* as simple, but the holotype of *H. edax* sp. nov. has an agnostoid articulation (Öpik 1967 : 72) which supports reference of *Hadragnostus* to the Agnostinae.

Hadragnostus edax sp. nov.
Pl. 11, figs 3–15

DERIVATION OF NAME. Latin, *edax*, greedy, referring to the swollen pygidial axis.

HOLOTYPE. A well-preserved pygidium, It 13463 (Pl. 11, figs 7, 8, 12).

TYPE LOCALITY AND HORIZON. Mila Formation, Sanghabad, Taleghan Range, Alborz Mountains, northern Iran.

FIGURED MATERIAL. Cephala It 13468 (Pl. 11, fig. 3), It 13483a (Pl. 11, figs 9, 10), It 13483b (Pl. 11, figs 14, 15), It 14023 (Pl. 11, fig. 11). Pygidia It 13463 (holotype, Pl. 11, figs 7, 8, 12), It 13471 (Pl. 11, fig. 13), It 13472 (Pl. 11, figs 4–6).

DESCRIPTION. Cephalic outline tends to be subquadrate, length about four fifths of width. Glabella three quarters of cephalic length, bilobed ; anterior lobe relatively small, nearly twice as wide as long, narrower than posterior lobe and one third of its length or less. Posterior lobe parallel-sided, rounded or slightly pointed behind, without lateral furrows or a median node, but some specimens have a faint posterior node (Pl. 11, fig. 15). Basal lobes triangular, inflated, connected behind glabella. Each cheek (excluding border) as wide as posterior glabellar lobe, tapering strongly forwards ; in front of the glabella the cheeks are narrower than the length of the anterior glabellar lobe and are faintly separated by a partial preglabellar median furrow which forms a shallow depression just in front of the glabella and shallows or fades out forwards. Laterally and frontally the cheeks curve down steeply to the border which is mainly flat and horizontal but has a narrow outer rim and is curved under at the edge.

Thorax unknown.

Pygidium strongly convex, transverse, length about three quarters of width. Axis large, extending back to overhang the posterior border furrow. At anterior end axis is just less than half the total pygidial width, and widens slightly backwards. The articulating furrow has a depression either side of the median line, giving a weakly diplagnostid character. A median tubercle at the highest point has its posterior end just in front of the mid-length of the axis. Irregularities in the axial furrow indicate the merest traces of lateral furrows opposite the front and back of the median tubercle. A small terminal node lies well above the border furrow. Each flank about two fifths as wide as axis in the larger specimens but proportionally wider – nearly half the axial width – in a small specimen about 1·1 mm long. Flanks slope steeply down to the border, narrow backwards, separated behind axis. Border broad and thick, of even width between the small posterolateral marginal spines. Surface smooth.

DISCUSSION. The present form is very similar to *Hadragnostus las* Öpik (1967 : pl. 58, figs 6–10) but has a slightly shorter and narrower anterior glabellar lobe. In *H. las* this lobe is more than one third of the length of the posterior lobe but in the present form it is less than a third. *H. las* has a stronger and wider preglabellar median furrow. The pygidial flanks are narrower, less than half the width of the axis, whereas in *H. las* they are more than half, and in Öpik's reconstruction (1967 : 103, text-fig. 24) the posterolateral marginal spines are shown as larger than those of *H. edax*.

One figured cephalon of *Hadragnostus modestus* (Lochman 1944 : pl. 5, fig. 10) is typical of the genus : the anterior glabellar lobe is narrower than the posterior lobe but it is longer than in *H. edax*. The preglabellar median furrow is narrower than that of *H. las* and stronger than in *H. edax*. The basal lobes of *H. modestus* are smaller than in either of the other species. Lochman's other figured cephalon has a more rounded outline, the posterior glabellar lobe is more tapered and the preglabellar field is longer ; it may represent another genus. The holotype and paratype pygidia of *H. modestus* are meraspids with the median tubercle at the mid-length of the pygidium. Full comparison with *H. edax* cannot be made.

Family **QUADRAGNOSTIDAE** Howell 1935

Genus *PERONOPSIS* Hawle & Corda 1847

TYPE SPECIES.   By monotypy, *Battus integer* Beyrich 1845.

Peronopsis fallax (Linnarsson 1869) aff. *minor* (Brögger 1878)

Pl. 12, figs 1–14

FIGURED MATERIAL.   Cephala It 13480a–b (Pl. 12, figs 1, 2), It 13480c (Pl. 12, figs 3, 4), It 13480d (Pl. 12, fig. 14), It 14024 (Pl. 12, figs 9, 11), It 14026 (Pl. 12, fig. 10).   Pygidia It 13467 (Pl. 12, fig. 6), It 13469 (Pl. 12, figs 12, 13), It 13485 (Pl. 12, figs 5, 8), It 14025 (Pl. 12, fig. 7).   Some twenty unfigured cephala and pygidia also present.

DESCRIPTION.   Cephalon rounded in front, nearly as long as wide.   Glabella about 0·7 of cephalic length, bilobed ; anterior lobe rounded in front, slightly narrower than, and less than two fifths the length of, the posterior lobe.   Transglabellar furrow narrow at external surface, broader in exfoliated specimens. Posterior glabellar lobe has faint lateral furrows at two fifths of its length from the front and a faint median node, generally elongate, at or in front of its mid-length ; bluntly rounded behind.   Basal lobes triangular but with a forward extension in some specimens which indents the sides of the glabella, somewhat as in *Ptychagnostus atavus* (Tullberg) ; this feature is not seen in exfoliated specimens.   Cheeks about as wide as glabella, narrowing forwards slightly, confluent in front.   A pit resembling an incipient preglabellar median furrow is seen in front of the glabella in some specimens.   Cheeks slope steeply down to border in small or exfoliated specimens, less steeply in the largest specimens.   Border furrow is a curve where the cheeks flatten out to form a border, and is broad in large specimens.   Border is a narrow convex rim.

Thorax unknown.

Pygidium convex, subquadrate, length about 0·9 of width.   Axis about two fifths of total width, parallel-sided with a tendency to narrow slightly at the anterior third.   Posterior end generally bluntly pointed but may be rounded, especially in large specimens, not reaching border.   Median tubercle at anterior two fifths ; traces of lateral furrows opposite anterior and posterior ends of tubercle.   Articulating device simple, basic (Öpik 1967 : 72).   Flanks (pleural lobes excluding border) about half the width of axis but proportionally narrower in specimens more than 2 mm long, and always confluent behind axis although the connection is narrow in some specimens.   Border furrow broad and shallow.   Border broad, of even width between the strong posterolateral marginal spines.   Surface smooth.

DISCUSSION.   In most features the present form falls within the wide range shown by Westergård's (1946 : pl. 3, figs 3–7) figures of *P. fallax minor*.   It differs from many *Peronopsis* species in that the pygidial flanks are confluent behind the axis, and resembles *P. fallax minor* but not *P. fallax ferox* (Tullberg) in the character of the cephalic border (Westergård 1946 : 38).   The cephala agree with Westergård's figures although the glabella is generally longer than in his fig. 4 and the anterior

glabellar lobe is proportionally longer than in his fig. 3 ; neither figure shows a preglabellar depression or elongated *Ptychagnostus*-like basal lobes. A specimen of *P. fallax* cf. *minor* (Pl. 12, fig. 15) from the *A. pisiformis* Zone of central England (Taylor & Rushton 1972 : 19) has a weak preglabellar depression but differs in having a longer anterior glabellar lobe and smaller basal lobes ; the pygidial axis is evenly rounded behind. Probably compression has caused the lateral margins of the pygidium to converge backwards slightly.

Some of the pygidia of '*Agnostus*' *simplexiformis* Rozova (1964 : 24) resemble that of the present form. Rozova figured no cephala of '*A.*' *simplexiformis* but Lazarenko & Nikiforov (1968 : pl. 3, figs 1–4) showed that both cephalon and pygidium have constricted acrolobes (Öpik 1967 : 68). Judging from these figures we would transfer '*A.*' *simplexiformis* to *Agnostoglossa* Öpik (1967 : 145).

Family DORYPYGIDAE Kobayashi 1935
Genus *DORYPYGE* Dames 1883

TYPE SPECIES. Original designation, *Dorypyge richthofeni* Dames 1883.

DISCUSSION. About forty specific names have been applied to *Dorypyge*, *sensu stricto*, but according to Kobayashi's revision (1960 : 347) many of these are synonyms. Kushan (1973) has discussed six forms from Iran.

Dorypyge sp.
Pl. 11, figs 1, 2

MATERIAL. One fragmentary pygidium about 7 mm long, It 13461.

DESCRIPTION. Outline, excluding spines, trapezoidal, width nearly 1·5 times length. Axis only slightly tapered backwards, composed of three well-defined rings, a fourth less well defined, and a rounded bulbous terminal part. Flanks slightly narrower than axis anteriorly, marked by three pairs of narrow pleural furrows but no interpleural grooves. Border broad, the anterior pleural furrows crossing it indistinctly. Medially, the border forms a narrow transverse connection behind the axis. Convex parts of surface covered with sparse coarse granules. The marginal spines are distinctive although not all are preserved. The pygidium follows the common plan of *Dorypyge* species in having four pairs of main marginal spines anterior to the largest pair, but the present form is unusual, and perhaps unique, in showing a small subsidiary spine anterior to each of the first three of the 'main' spines ; their bases make the outline of the pygidium jagged. Whereas the thickness of the 'main' spines increases from the first to fourth pair, the subsidiary spines are progressively thinner from the first to third pair. The fifth pair of marginal spines is represented only on the left by a scar where the spine is broken off ; it was twice as thick as the fourth spine. The outline of the posterior part of the pygidium suggests the former presence of a substantial sixth pair of spines. The doublure, which is partly exposed, is a smooth band parallel to the margin and convex ventrally.

DISCUSSION.   The present form differs from all species so far described in having subsidiary pygidial spines.   However Dr P. Jell has told us of certain *Kootenia* species which also show 'subsidiary' marginal spines which point more nearly ventrally and are correspondingly difficult to observe.   Their presence suggests that similar spines may be found in other Dorypygidae.   In other respects the present form resembles the subspecies *D. richthofeni laiwuensis* Kobayashi, which lacks interpleural grooves, and the form figured by Sun (1924 : pl. 2, figs 3 c, d) which Kobayashi (1960 : 348) referred to *D. r. laevis*.   Sun's fig. 3d shows that the marginal spines increase in size backwards and also shows sparse granulation, but it differs in having slightly wider flanks and only three axial rings.   The present specimen is distinguished from *D. iranensis* Kushan and *D. khademi khademi* Kushan by the granular surface, and from *D. khademi papillosa* Kushan by the absence of interpleural grooves.   The fragment illustrated by Kushan (1973 : pl. 28, fig. 8) as *D. richthofeni* n. subsp. aff. *richthofeni* differs slightly in having wider axial ring furrows and pleural grooves, and a wider (sag.) post-axial part of the border.

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Family **ASAPHISCIDAE** Raymond 1924

Genus *IRANOLEESIA* King 1955

(*Pro Irania* King 1937, *non* De Filippi 1863)

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DIAGNOSIS.   Asaphiscid trilobites with glabella slightly tapering, truncate anteriorly.   Posterior two pairs of glabellar furrows deep, inner half of 1P bifurcate, posterior branch directed obliquely backwards.   Occipital ring may be subdivided with lateral lobes.   Postocular fixed cheeks small (sag., trans.).

TYPE SPECIES.   Original designation, *Irania pisiformis* King 1937.

DISCUSSION.   The type species (and, with the removal from *Iranoleesia* of *Irania falconi* King 1937, the only species) of *Iranoleesia* is redescribed below.   Kobayashi (1967 : 439) indicated that *Iranoleesia* may be a junior synonym of *Hundwarella* Reed 1934, from the Cambrian of Kashmir.   The two specimens on which the type and only species of *Hundwarella* is based, both cranidia, show apparently bifurcate inner ends of the 1P glabellar furrows (Reed 1934 : pl. II, figs 5, 6) which connect across the middle of the glabella.   This is not the case in *Iranoleesia pisiformis*, but the Kashmir specimens are slightly crushed, and the apparent transverse furrows may be the result of compressing bifurcate furrows of *Iranoleesia* type.   A similar effect may be observed on flattened specimens of *Hypermecaspis* (compare Fortey 1974 : pl. 13, fig. 1 with Lake 1913 : pl. 7, fig. 3).   Even if this is accepted *Iranoleesia pisiformis* differs from *Hundwarella* in having a transversely truncate front margin of the glabella, the preglabellar field only half as wide (sag.), and a strongly punctate surface sculpture.   Since the significance of such characters in discriminating asaphiscid genera is still imperfectly appreciated, *Iranoleesia* is therefore retained here pending a revision of the whole group.   For example, the genus *Iniotoma* Öpik 1967, from the Mindyallan, has apparently similar glabellar furrows (Öpik 1967 : 232, fig. 81) to those of *Iranoleesia*, but they are less impressed and the eye ridges are less distinct (1967 : pl. 11, figs 1–3).   While it seems probable

that these genera are separated more by geography than by morphology, a revision of the genera is beyond the scope of the present account. The genus *Protohedinia* Endo 1937 (the type species of which has been illustrated by Chang 1963 : pl. 1, fig. 9) has glabellar furrows similar to those of *Iranoleesia* and has palpebral lobes similarly placed, eye ridges of like prominence, and border and preglabellar fields of similar proportions. It is difficult to see why it has been included in a separate family Tengfengiidae by Chang (1963 : 458).

Iranoleesia pisiformis (King 1937)
Pl. 9, figs 6, 8–10, 12

1937 *Irania pisiformis* King : 12–13 ; pl. II, figs 6a–c

DIAGNOSIS. *Iranoleesia* species with pitted surface sculpture. Anterolateral corners of glabella angulate. Anterior border furrow without plectrum.

HOLOTYPE. Although not named as such, it is clear from the plate description and measurements given by King (1937 : 13 ; pl. II, fig. 6) that he intended the incomplete cranidium, GSI 16305, as holotype of this species. We figure a cast of this original on Pl. 9, fig. 6.

TYPE LOCALITY AND HORIZON. Ma'dan, locality 12 of King (1937). The exact stratigraphic relationship of this species to the new *Chelidonocephalus* fauna is not known for certain but Kushan recorded *I. pisiformis* only from horizons below those with *Koldiniella mitella*, suggesting that the *Chelidonocephalus* fauna is slightly the younger.

FIGURED MATERIAL. Cranidia In 36890 (cast of holotype, Pl. 9, fig. 6), In 36910 (Pl. 9, fig. 8), In 36911 (Pl. 9, fig. 10), In 36912 (Pl. 9, figs 9, 12).

DESCRIPTION. Only cranidia known with certainty, and available material largely decorticated, but otherwise well preserved in a limestone matrix. General cranidial outline subquadrate, with anterior margin not greatly protruded, glabella but slightly elevated above fixed cheeks, sloping downwards anteriorly into pre-glabellar field. Glabella (with occipital ring) almost rectangular, extending to three quarters cranidial length, tapering very gently forwards, so that the axial furrows enclose an angle of about 15°. Anterolateral corners of the glabella are obtusely angulate, resulting in a truncate anterior glabellar margin. Four pairs of lateral glabellar furrows, of which the anterior two pairs are shallow and probably would not be visible on the dorsal surface of the cuticle. 1P has its outer end opposite the midpoint of the palpebral lobe, its outer third running transversely or slightly posteriorly, at which point it bifurcates into a short, slightly anteriorly-directed branch, and a longer, strongly backward-directed posterior branch, the inner end of which terminates at about one third glabellar length. 2P, with its outer end almost opposite the front of the palpebral lobe, is arcuate, the inner end curving backwards in line with the inner end of 1P. 3P and 4P opposite the eye ridge, the former isolated within the glabella, transverse, the latter short, slightly forward-inclined, placed laterally to 3P. Occipital furrow deep, forward-curved medially,

and shallowing laterally ; occipital ring with indistinctly defined lateral lobes and prominent median tubercle. Axial furrows distinct, as is the preglabellar furrow on the smaller cranidium (Pl. 9, fig. 8), although on larger specimens this furrow becomes shallower to almost effaced medially.

Intraocular fixed cheeks about half width (trans.) of adjacent glabella, horizontal. Preglabellar field about one sixth length of glabella (sag.), scarcely downsloping medially ; that part of the fixed cheeks in front of the eye ridge slopes downwards more steeply and is about twice the length (exsag.) of the preglabellar field (seen in dorsal view). The eye ridges are strong on internal moulds, converging forwards at about 65° to the sagittal line. Palpebral lobes of about same width as the eye ridges, in a posterior position such that the transverse line connecting their anterior limits crosses the glabella at two thirds its length ; they are of length (exsag.) one third, or slightly less, that of glabella. Anterior border furrow defining change in slope from preglabellar field to broad, backward-sloping anterior border, the width of which (sag., exsag.) is similar to that of the preglabellar field. Postocular cheeks poorly shown by present material.

Genus *ANOMOCARELLA* Walcott 1905

DIAGNOSIS. Asaphiscid trilobites with glabellar furrows faint or absent ; preglabellar field less than one fifth glabellar length ; anterior border furrow with narrow (trans.) plectrum ; anterior border flat. Pygidium with distinct flat border.

TYPE SPECIES. Original designation, *Anomocarella chinensis* Walcott 1905.

DISCUSSION. The species described below as *Anomocarella falconi* was originally assigned to *Irania* by King (1937), and hence subsequently to *Iranoleesia*. Kobayashi (1967 : 493) preferred to regard the species as belonging to *Grandioculus* Cossmann. The type species of that genus, *G. megalurus* (Dames) (Dames 1883 : 20 ; pl. 1, figs 7, 8, 10. Walcott 1913 : 192 ; pl. 18, figs 9a–f) has large, somewhat posteriorly placed palpebral lobes, weakly defined glabellar furrows and a flat border like that of the Iranian specimens, but the border furrow lacks a plectrum, which is also the case in *Iranoleesia pisiformis*. The type species of *Anomocarella* is *A. chinensis* Walcott 1905, the lectotype of which was carefully identified by Endo & Resser (1937 : 164–165). This cranidium is only one of the specimens used by Walcott (1913 : pl. 20, figs 3, 3a–d, 4, 4a) to illustrate *A. chinensis*, and all the others are from a different locality from the lectotype (pl. 20, fig. 3c) and include more than one species (Endo & Resser 1937 : 165). It is the other material (the specimens of Walcott 1913 : pl. 20, figs 3, 3e) that is used to illustrate the type species of *Anomocarella* in the Treatise (Howell *in* Harrington *et al.* 1959 : 292). Endo & Resser emphasized the presence of a plectrum as 'the most distinctive generic feature' of *Anomocarella*, with which we agree. The major point of difference between the Iranian material and the type species is the shorter preglabellar field of the latter ; this is not regarded as of generic importance, as it is a variable feature in other species assigned to *Anomocarella* by Endo & Resser (1937). Further backward migration of the plectrum (or further shortening of the preglabellar field)

results in the broadly backward-deflected border furrows seen in *Mapania* (Öpik 1961 : fig. 53).

Anomocarella and allied genera are sometimes referred to a separate family Anomocarellidae Hupé 1955. Since the characters pertinent to the division of genera within the Asaphiscidae and *Anomocarella*-group are unclear at best, and there is no phyletic concept on which to base separate families, *Anomocarella* is here retained doubtfully within the Asaphiscidae.

Anomocarella falconi (King 1937)

Pl. 9, fig. 11 ? ; Pl. 10, figs 1–5, 8

1937 *Irania falconi* King : 13–14 ; pl. II, figs 7a–f.

DIAGNOSIS. An *Anomocarella* species with transverse width of plectrum half to two thirds that of anterior margin of glabella ; preglabellar field of moderate width ; dorsal surface of cuticle minutely granulose.

HOLOTYPE. An external mould of a cranidium, a cast from which was figured by King (1937 : pl. II, fig. 7a), GSI 16306. This cast is here refigured on Pl. 10, fig. 1.

TYPE LOCALITY AND HORIZON. Mila Formation at Darreh Shu (lowest beds), locality 8 of King (1937), whence *Chelidonocephalus alifrons* is also recorded (King 1937 : 17).

FIGURED MATERIAL. Cranidia In 36891 (cast of holotype, Pl. 10, fig. 1), In 36908 (Pl. 10, fig. 3), In 36909a (Pl. 10, fig. 2), In 36909b (Pl. 10, figs 4, 5, 8). Doubtfully assigned pygidium In 36892 (cast, Pl. 9, fig. 11).

DESCRIPTION. Cranidium of low convexity, downward-sloping in front of eye ridges, glabella not greatly vaulted above intraocular cheeks. Maximum cranidial width at posterior margin about one and a half times transverse width at anterior border. Glabella extends to about three quarters cranidial length, and tapers uniformly forwards, the axial furrows enclosing an angle between 15° and 20°. Anterolateral corners of glabella rounded ; axial furrow deeper than preglabellar furrow, and both better defined on internal moulds. Occipital and glabellar furrows faint, best seen as smooth, slightly depressed areas on specimen retaining exoskeleton (Pl. 10, fig. 8). 1P to 3P almost touch axial furrows ; distance (exsag.) between 1P and 2P equal to that between 1P and the occipital furrow, but less than that between 2P and 3P ; 3P is level with the point at which the eye ridges touch the glabella, transverse ; 1P and 2P slope slightly backwards. 4P is very close to 3P but external to it, continuing in line with the furrow defining the posterior of the eye ridge. Occipital ring widest (sag.) medially, defined by broad, shallow furrow, of which only the transverse, median section is visible on the internal mould (Pl. 10, fig. 3) ; outer ends of this section deepened into internal muscle scars. External surface shows narrow parafrontal band in front of midpart of frontal glabellar lobe ; this band extends further laterally on the internal mould, but neither on dorsal nor on ventral surfaces is the connection with the eye ridge displayed.

Palpebral lobes of half length of glabella, anterior limit opposite outer ends of 3P furrows ; palpebral rims broad, defined by shallow palpebral furrows which are outward-bowed medially.   Maximum transverse width of intraocular cheek half width of adjacent glabella.   Eye ridges not visible abaxially on dorsal surface of exoskeleton, but their confluence with the frontal lobe of the glabella is clearly shown by anterior shallowing of the axial furrows.   The eye ridges, where seen, are only slightly oblique, virtually transverse on the smallest cranidium.   Postocular fixed cheeks narrow, width (exsag.) less than that of occipital ring, bisected by strong border furrow.   Narrow posterior border carries small articulating socket (?) at about mid-width, maximum transverse width of border less than that of occipital ring.   Preglabellar field of length (sag.) between 0·14 and 0·17 times glabellar length on available material.   Anterior border furrow marks an abrupt change in slope anterolaterally, where it is gently bowed forwards ; medially there is a distinct plectrum, of transverse width about half to two thirds that of frontal lobe of glabella. Laterally the wide anterior border is horizontal to slightly declined, but in front of the plectrum more nearly carries forwards the downward slope of the preglabellar field.   There are faint indications of caeca crossing the border furrow.   The dorsal surface of the exoskeleton is covered with minute granules.

An incomplete pygidium (Pl. 9, fig. 11) was assigned to this species by King (1937 : pl. II, fig. 7b).   It has a convex rhachis showing three or four axial rings and a broad flattened border.   It also resembles the posterior part of the pygidium here tentatively assigned to *Chelidonocephalus preannulatus* sp. nov. (p. 338), and it must be admitted as a possibility that the pygidium is that of *C. alifrons*.   Our material is inadequate to resolve the question.

DISCUSSION.   *Anomocarella falconi* differs from the type species *A. chinensis* (Walcott 1913 : pl. 20, fig. 3c.   Endo & Resser 1937 : pl. 34, fig. 6) in having less oblique eye ridges (due to an anterior forward limit of the palpebral lobe) and a longer (sag., exsag.) preglabellar field ; the surface sculpture of *A. chinensis* is described as punctate.   Of the many species assigned by Walcott (1913 ; some re-illustrated in Lu *et al.* 1965 : pls 59–61) to *Anomocarella* only the type species has a plectrum, and the others should be excluded from the genus.   One of the species from the Mapan Formation, *A. concava* Endo & Resser (1937 : 167 ; pl. 35, fig. 8), approaches *A. falconi* closely in the proportions of preglabellar field and plectrum. It differs only in having a glabella that hardly tapers forwards, and anterior limits of the palpebral lobes that approach the glabella more closely.

Genus *KOLDINIELLA* Sivov 1955

TYPE SPECIES.   Original designation, *K. mitella* Sivov 1955.

DISCUSSION.   This genus is characterized by a broad, flat cephalic border and effacement of the other cephalic characters.   Traces of the axial furrow suggest that the glabella extends to or nearly to the anterior border (Kushan 1973 : pl. 31, fig. 3) ; this feature, the more backward eyes and the transverse pygidium distinguish *Koldiniella* from the more effaced forms of *Maryvillia* and *Blountia* (Rasetti 1965 :

pls 9, 10). *Koldiniella* is similar to but more effaced than the asaphiscid *Peishania* Resser & Endo from the late Middle Cambrian ; it may even have been derived from a form like *P. lubrica* Chang (1957 : pl. 1, fig. 2) which has a comparable frontal border but has the axial furrows and occipital furrow more distinct. *Peishania* (and *Liopeishania* Chang 1963, to which *P. lubrica* was transferred in Lu *et al.* 1965) have longer pygidia than *Koldiniella mitella*. The dorsal surface of the cranidium of *Liopeishania spannensis* Palmer & Gatehouse is more effaced than other species and approaches *Koldiniella* in this respect. It differs in having a shorter anterior border which is curled down and under in front (Palmer & Gatehouse 1972 : pl. 4, fig. 10).

Koldiniella has been variously grouped with the families Illaenidae, Illaenuridae and Tsinaniidae on account of its effaced cephalon, but there are no characters uniting it convincingly with any of these families and the frontal border is a feature distinguishing it from all (and from *Kingstonia*). It perhaps comes closest to the Illaenuridae because *Illaenurus* has a transverse pygidium and in *Macelloura* the glabella reaches to the frontal border.

Koldiniella mitella Sivov 1955

Pl. 10, figs 6, 7, 9, 10, 15, 13 ?, 14 ?, 16 ?

FIGURED MATERIAL. Cranidium It 14021 (Pl. 10, figs 6, 7) ; pygidia It 13477 (Pl. 10, figs 9, 10), It 14022 (Pl. 10, fig. 15) ; hypostome assigned to the species It 13506 (Pl. 10, fig. 16) ; cranidium doubtfully assigned, It 13476 (Pl. 10, figs 13, 14). Ten unfigured specimens also present.

DISCUSSION. Kushan (1973 : 149) redescribed this species using material from Iran. Material in the present collection is identical. A hypostome tentatively referred to *K. mitella* (Pl. 10, fig. 16) has a gently convex median body divided by a faint transverse furrow. The lateral border widens out posterolaterally but is narrow posteromedially. The surface is smooth except posterolaterally where it is striated parallel to the margin. This hypostome cannot be that of *Dorypyge* because it differs from that referred to *Dorypyge aenigma* (Westergård 1948 : pl. 2, fig. 7) ; the smooth surface and striated margin recall *Koldiniella mitella* rather than the associated *Chelidonocephalus preannulatus*.

K. mitella is distinguished from *K. convexa* Lazarenko by the longer and flatter anterior border and by the weaker axial furrows at the base of the glabella (Rozova 1964 : pl. 15, figs 1–5).

K. prolixa Lazarenko (*in* Lazarenko & Nikiforov 1968 : pl. 1, figs 16–19) has a longer, more salient frontal border and a much longer pygidium, nearly as long as wide.

One small cranidium 1·7 mm long (Pl. 10, figs 13, 14) has a much narrower (sag.) frontal border, less than a tenth of the length of the cranidium. It may possibly be a juvenile form of *K. mitella* because among larger specimens the border seems to have grown more rapidly than the rest of the cranidium, but the border is convex instead of being flat or even slightly concave as it is in specimens of *K. mitella* 3 mm or more in length. The small cranidium may therefore be referable to *Parakoldinia* Rozova

1960. It is most closely comparable with *P. plana* Rozova (1960 : pl. 7, figs 1–5), a broad and not especially convex species with a distinct frontal border, horizontal in front view, which does not show strong striae. Unfortunately the present specimen is too different in size for an exact comparison to be made, but Rozova's fig. 3 shows the border furrow more sharply cut and the border dropping abruptly downwards in front, whereas in the present specimen the border curves down more gradually in front.

Genus *TSINANIA* Walcott 1914

TYPE SPECIES. Original designation, *Illaenurus canens* Walcott 1905.

DISCUSSION. Kobayashi (1935 : 303) has suggested that *Tsinania* is an effaced member of the Asaphiscidae.

Tsinania ? sp.
Pl. 10, figs 11, 12, 17–19

FIGURED MATERIAL. Cranidia It 13493 (Pl. 10, figs 11, 12), It 13458 (Pl. 10, figs 17–19).

DESCRIPTION. Cranidium convex. Axial furrows effaced at external surface but a trace of their ends seen on the exfoliated specimen. The base of the glabella is a little more than half as wide as the cranidium. No trace of occipital or glabellar furrows. In palpebral view the middle of the eyes lies just behind the mid-length. Palpebral furrow very faint. Preocular sutures diverge forwards slightly but curve inwards across the anterior border. Postocular sutures diverge backwards obliquely, straight. A very faint border furrow separates off a narrow, barely differentiated frontal border. Pleuroccipital furrow weak. Surface smooth.

DISCUSSION. These specimens agree closely with *Tsinania canens* (Walcott 1913 : pl. 23, fig. 2) except that the eyes seem farther forward, the base of the glabella is wider and there is a very faintly marked border. Kobayashi (1952) revised *Tsinania canens* and showed that the glabella is less than half as wide as the cranidium. No published figures show a frontal border. *Tsinania* ? sp. also resembles *Plethometodus obtusus* Rasetti (Longacre 1970 : pl. 6, figs 14, 15) except that the latter has a well-marked occipital furrow and curved postocular sutures. *Plethometopus convergens* (Raymond) has only a weak occipital furrow but the preocular sutures converge forwards (Longacre 1970 : pl. 3, figs 11, 12). *Plethopeltoides lepidus* Lazarenko (*in* Lazarenko & Nikiforov 1968 : pl. 9, figs 1–7) has a better-marked occipital furrow and is less convex. *Wanwanoglobus convexus* (Kobayashi 1966 : 265 and text-fig. 4) has a much more convex cranidium. We know of no Cambrian trilobite which matches the present cranidium in all details.

Family UNCERTAIN
Genus *CHELIDONOCEPHALUS* King 1937

DIAGNOSIS. Cranidium opisthoparian, 'ptychoparioid', with glabellar furrows (other than occipital) not incised. Broad false border furrow delimiting flattened

or gently convex anterior cranidial border. True border furrow crosses preocular cheek, cut by preocular suture at sutural mid-length (exsag.), inner ends of border furrow curve backwards to define the plectrum. Narrow (sag.), transverse inflated band in front of glabella. Broad palpebral lobes between one third and half glabellar length, posterior limits opposite outer parts of occipital furrow defining narrow (exsag.) postocular cheek. Width of intraocular cheek less than that of adjacent glabella. Eye ridges subdued.

TYPE SPECIES. Original designation, *C. alifrons* King 1937.

DISCUSSION. *Chelidonocephalus* was placed in the Alokistocaridae in the Treatise (Howell *in* Harrington *et al.* 1959 : 238), but other possibilities must now be considered. Chang (1959 : 223) allied *Chelidonocephalus* with a number of Middle Cambrian genera from China, including *Poshania* Chang 1957 (type species *P. poshanensis* Chang 1957), *Peichishania* Chang 1957 (type species *Eymekops rectangularis* Endo & Resser 1937), *Inouyella* (type species *I. peiensis* Endo & Resser 1937), *Ordosia* (type species *O. fimbricauda* Lu 1954) and *Taitzuia* (type species *T. insueta* Endo & Resser 1937). All these genera share with *Chelidonocephalus* the backward-curved border furrow (termed below the 'true' border furrow), although the development of the border itself is variable. In the Treatise (Harrington *et al.* 1959) *Chelidonocephalus*, *Ordosia*, *Inouyella* and *Taitzuia* are assigned to four different superfamilies, while Chang (1959 : 223) indicates that they may be included within a single family Namanoiidae Lermontova 1951, based on the Lower Cambrian genus *Namanoia* from eastern Siberia, which has a similar disposition of furrows on the cranidial margin. We believe that the form of the border furrows is assuredly significant at generic level, but that its significance at family level is more contentious. The backward-curving border furrows are present, for example, on *Llanoaspis walcotti* Resser (Rasetti 1965 : pl. 8, fig. 14) from the Upper Cambrian of Tennessee, which is certainly unrelated to *Chelidonocephalus* and the other genera listed above, having distinctively different facial sutures. Similarly *Namanoia*, with its quadrate glabella and lack of parafrontal band, is unlikely to be closely related to *Chelidonocephalus*, which therefore cannot be assigned to the Namanoiidae.

We consider that *Chelidonocephalus* is most nearly related to *Poshania*, which is identical in the combination of true border furrow and parafrontal band (Chang 1959 : pl. 2, figs 4, 5), and differs significantly only in lacking a distinct false border furrow. The resemblance is perhaps more apparent when comparing small cranidia of *Chelidonocephalus* (Pl. 9, fig. 5) with adult *Poshania* as the whole border region is then of similar proportions. *Peichishania*, *Inouyella*, *Ordosia* and *Taitzuia* are probably unrelated to these two genera ; *Peichishania* was assigned by Öpik (1967 : 221) to the Auritamidae, *Ordosia* by Lu (1954) to the Leiostegiidae (and *Taitzuia* closely resembles *Ordosia*). *Inouyella*, with its tapering glabella with narrow, backward-directed furrows (Endo & Resser 1937 : pl. 46, figs 9, 14), is probably unrelated to any of the foregoing.

The Alokistocaridae have been included within the concept of the Papyriaspididae by Öpik (1961 : 149). He (Öpik 1967 : 298) includes *Poshania* (misspelt *Poshauia*) in the family Mapaniidae of his superfamily Rhyssometopacea, which might therefore

be expected to include *Chelidonocephalus* also.   We briefly discuss below (p. 337) some reasons for treating a rhyssometopacean affinity with caution.

This discussion shows to what an extent the familial (and superfamilial) concepts are capable of varied interpretations in these late Middle to early Upper Cambrian forms.   For the time being, therefore, we have to leave *Chelidonocephalus* as of uncertain family.

Chelidonocephalus alifrons King 1937

Pl. 8, figs 1–5

DIAGNOSIS.   *Chelidonocephalus* species with punctate surface sculpture.   Anterior border of cranidium gently convex.   Palpebral lobes farther from glabella, and convexity lower than that of *C. preannulatus* nov. sp. (p. 338).

LECTOTYPE.   King (1937) did not specify a holotype for this species, but of his original syntypic series that figured in his pl. II, fig. 8A corresponds with the measurements cited in the text, and was probably intended as the type.   We therefore select this specimen, GSI 16311, as lectotype.

TYPE LOCALITY AND HORIZON.   The lectotype is associated with *Anomocarella falconi* (King) from a limestone 2300 feet (700 m) below the local top of the Cambrian, at Chal-i-Sheh (loc. 3 of King 1937 : text-fig. 1).   The evidence from Kushan's (1973) faunal lists with *Chelidonocephalus* is that a late Middle Cambrian or an earliest Upper Cambrian age is most probable for these beds.

FIGURED MATERIAL.   Cranidia In 36893 (cast of lectotype, Pl. 8, fig. 1), In 36895 (Pl. 8, figs 2, 3, 5), In 36896 (Pl. 8, fig. 4).

DESCRIPTION.   Cranidia only identified with certainty, these being well preserved in limestone.   Convexity is low, the whole surface of the cranidium sloping gently downwards and forwards from the occipital ring.   The largest specimen, a fragmentary cranidium, probably had a cephalic length of about 20 mm.   Maximum transverse width, across posterior margin, about one and a half times the width across the anterior cranidial margin.   Glabella tapering gently forwards, axial furrows enclosing an angle of about 30°, extending to about 0·7 of the cranidial length (sag.) ;   front margin truncate.   Glabellar furrows absent, but muscle insertion areas are represented by smooth areas lacking the pitted sculpture which covers the rest of the glabella.   There is a pair of large smooth areas centred on the lateral parts of the occipital furrow, and three (? four) pairs of ill-defined smooth areas on the flanks of the glabella.   The occipital furrow is shallow except where deepened into pits near its lateral extremities.   Postocular and preocular fixed cheeks downsloping ;   intraocular cheek horizontal.   Palpebral lobes about one third glabellar length, with posterior limits slightly in front of points at which the occipital furrow meets the axial furrows.   Transverse width of the intraocular cheek at anterior limit of palpebral lobe is about 0·7 of the width of glabella at same section.   Palpebral furrows are faint even on internal moulds.   Eye ridges are

faint on the external surface of the cuticle, but clearly visible on internal moulds (Pl. 8, fig. 4) ; their adaxial limits indent the course of the axial furrows.   Posterior border furrow deep and transverse ; convex posterior border of width (exsag.) sub-equal to that of furrow.   In front of the glabella there is a narrow (sag., exsag.) transverse inflated band, defined posteriorly by the preglabellar furrow and an-teriorly by the true anterior cranidial border furrow.   This latter follows a trans-verse, gently curved course a little anterior to the front margin of the glabella, medially deflected sharply backwards when approaching the anterolateral corners of the glabella, to form the median plectrum (Öpik 1967 : 58), this area being inflated above the genal areas adjacent to it.   The anterior border furrow is cut by the anterior branch of the facial suture at, or slightly in front of, the anterior sutural mid-length.   In front of the plectrum the preglabellar field continues a gently downward slope into a broad, shallow false border furrow.   The gently convex anterior border widens medially, where it occupies one third to one quarter of the total preglabellar length.   Internal moulds are strongly caecate on frontal part of cranidium ; caeca pass over both border furrows, but are not visible behind eye ridge.   Dorsal surface of cranidium is finely pitted except in furrows and over muscle insertion areas.   In front of the true border furrow, the pits are replaced by more densely crowded, minute granules.

DISCUSSION.   The description of 'true' and 'false' border furrows used above needs clarification.   It is contended that the posterior of the two transverse furrows crossing the preglabellar area represents the border furrow as understood in other trilobites, and that the anterior furrow in *Chelidonocephalus* is independently generated.   Homologically, all that area anterior to the true border furrow should be termed 'anterior border', but for convenience the area is divided into preglabellar field, 'false' border furrow and anterior border in line with other trilobites.   The identification of the posterior of the two furrows with the anterior border furrow of other trilobites is based on the fact that this furrow has a median plectrum, and that the plectrum is invariably developed on the anterior border furrow.   Since plectra are developed in a number of groups which are, at least on present classi-fications, only distantly related, its presence may be taken as showing the position of the true anterior border furrow.   The important defining character of *Chelidonocephalus* is the presence of two anterior furrows.   It is interesting to note that some forms comparable in this respect are to be found in the superfamily Rhyssometopacea Öpik (1967 : 272) described from the Mindyallan of Australia, for example *Rhyssometopus princeps* Öpik (1967 : pl. 27, fig. 1–3 ; text-fig. 96), if we can accept Öpik's 'frontal wrinkle' (*ibid*. : text-fig. 93) as homologous to our true border furrow. However, rhyssometopaceans show impor-tant differences from *Chelidonocephalus*, notably in having large palpebral lobes close to the glabella, and we are unable to classify our species with the Australian superfamily.

A comparative description of *Chelidonocephalus preannulatus* sp. nov. is given below, which extends the concept of the genus to include forms with larger palpebral lobes, closer to the glabella.   They do not, however, approach rhyssometopaceans in this respect.

Chelidonocephalus preannulatus sp. nov.

Pl. 8, figs 6–8 ; Pl. 9, figs 1, 2, 5, 3 ?, 4 ?, 7 ?

DIAGNOSIS. *Chelidonocephalus* species with granulate surface sculpture. Anterior border broad and flat. Palpebral lobes larger, placed closer to the glabella than in *C. alifrons*, and convexity and furrow incision generally greater.

DERIVATION OF NAME. Latin – 'with a ring in front' – referring to the inflated, transverse preglabellar band.

HOLOTYPE. BM(NH) It 13503, incomplete cranidium partly preserving exoskeleton, figured on Pl. 9, fig. 2.

TYPE LOCALITY AND HORIZON. Mila Formation, Sanghabad, Taleghan Range, Alborz Mountains, northern Iran.

FIGURED MATERIAL. Cranidia It 13478 (Pl. 8, figs 6–8), It 13504 (Pl. 9, fig 5) ; free cheek It 13499 (Pl. 9, fig. 1) ; hypostoma, tentatively assigned, It 14020 (Pl. 9, figs 3, 4) ; pygidium, tentatively assigned, It 13460 (Pl. 9, fig. 7). Six unfigured fragments also present.

DISCUSSION. Since this species is similar to the type species *C. alifrons* in most proportional characters, a detailed description need not be repeated here. *C. preannulatus* differs from the type species in the following characters.

(i) Convexity (sag., exsag.) is greater, this being due to the increase in the downward deflexion of the fixed cheek in front of the palpebral lobes.

(ii) Anterior border is flat, not gently convex, forming a broad, horizontal rim around the cranidial margin. The border occupies about half (sag.) the preglabellar width, although the false border furrow, except on small cranidia, is ill defined.

(iii) Anterior branches of the facial sutures appear more divergent in dorsal view, this being due to the greater downward inclination of the preocular cheeks.

(iv) Length of palpebral lobes about half length of glabella. They are also closer to the glabella, such that the transverse width of the intraocular cheek at the anterior limit of the palpebral lobe is about half width of glabella at same section (0·7 times in *C. alifrons*).

(v) Furrows more deeply incised.

(vi) Surface sculpture of fine granules on glabella. Smooth areas on the glabella of one specimen (Pl. 8, figs 6–8) display the muscle insertion areas rather better than *C. alifrons*. Lateral occipital impression deep, producing a lateral narrowing of the occipital ring. 1P subcircular, indistinct, isolated within glabella near midline ; 2P of similar size and form adjacent to axial furrow opposite mid-part of palpebral lobe ; 3P opposite anterior end of palpebral lobe, narrow and transverse ; 4P of similar form, slightly anteriorly directed.

A free cheek (Pl. 9, fig. 1) shows a prominent eye socle, faint caeca radiate from the eye and there is a lateral continuation of the true and false border furrows which describe a ridge on the border. The counterpart shows the base of a strong genal spine.

A small hypostoma (Pl. 9, figs 3, 4) may belong to *C. preannulatus*. It is different from that assigned to *Koldiniella*, and from that of *Dorypyge*, so that

Chelidonocephalus is the most likely polymerid known from the present fauna to which it could belong. A distinctive feature is a prominent anterior hump on the middle body.

An incomplete associated pygidium is tentatively referred to this species because it shows traces of similar granular sculpture. The axis is wider than the flanks, tapers back, is rounded behind but tends to pass into a postaxial ridge ; it is composed of 4–5 rings and a terminal piece. Flanks show two distinct and one less clear pleural furrows. No interpleural furrows. There is a suggestion of a flattened lateral border.

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R. A. FORTEY, Ph.D.
Department of Palaeontology
BRITISH MUSEUM (NATURAL HISTORY)
CROMWELL ROAD
LONDON SW7 5BD

A. W. A. RUSHTON, B.A., Ph.D.
INSTITUTE OF GEOLOGICAL SCIENCES
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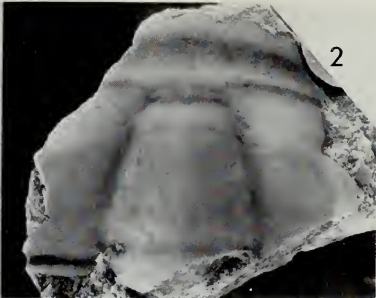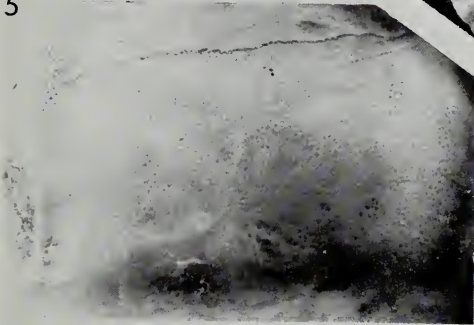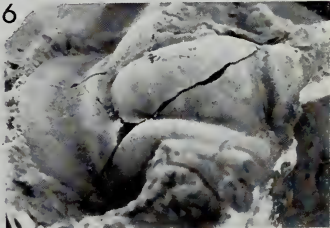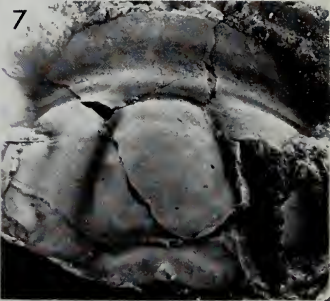LONDON SW7 2DE

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PLATE 8

Chelidonocephalus preannulatus sp. nov. (p. 338 ; see also Pl. 8, figs 6–8)

Mila Formation, near Sanghabad, Alborz Mountains

FIG. 1.   Fragmentary free cheek, × 8.   It 13499.

FIG. 2.   Holotype, partially exfoliated cranidium, × 8.   It 13503.

FIGS 3, 4.   Hypostoma attributed to this species, ventral view, and lateral view to show anterior hump, × 10.   It 14020.

FIG. 5.   Smallest cranidium, × 15.   It 13504.

FIG. 7.   Pygidium probably attributable to this species, fragmentary, × 4.   It 13460.

Iranoleesia pisiformis (King 1937) (p. 329)

Mila Formation, Ma'dan, Loc. 12 of King 1937

FIG. 6.   Cast of holotype, incomplete cranidium, × 5.   Original specimen figured by King 1937 : pl. 2, fig. 6a, GSI 16305 (cast In 36890).

FIG. 8.   Two cranidia, one retaining part of the cuticle and showing punctate surface sculpture, × 6.   In 36910.

FIGS 9, 12.   Internal mould of incomplete exfoliated cranidium, dorsal and lateral views, × 10. Note punctation on internal surface.   In 36912.

FIG. 10.   Internal mould of cranidium, × 5.   In 36911.

Anomocarella falconi (King 1937) ? (p. 331)

Mila Formation, Darreh Shu, Loc. 8 of King 1937

FIG. 11.   Cast of incomplete pygidium, × 6 ; original figured by King 1937 : pl. 2, fig. 7b, and there attributed to *A. falconi*, but possibly belonging to *Chelidonocephalus alifrons* (p. 332). GSI 16307 (cast In 36892).
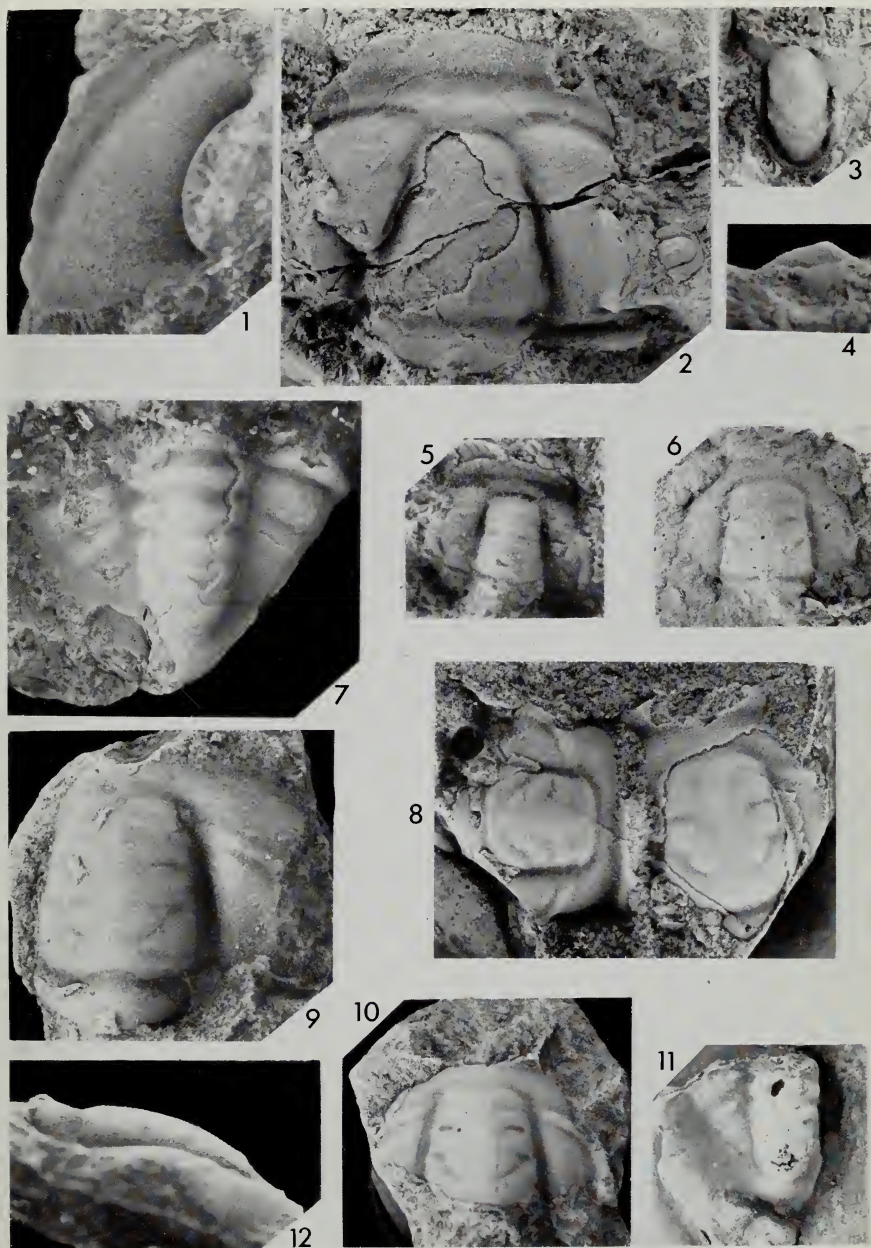
PLATE 9

PLATE 10

Anomocarella falconi (King 1937) (p. 331 ; see also Pl. 9, fig 11)

Mila Formation, Darreh Shu, Loc. 8 of King 1937

Fig. 1.   Latex impression taken from a cast of the holotype, external mould of cranidium, × 4. Original of King 1937 : fig. 7a, GSI 16306 (cast In 36891).

Fig. 2.   Small well-preserved cranidium retaining exoskeleton, dorsal view, × 10.   In 36909a. Same rock fragment as cranidium, Fig. 4.

Fig. 3.   Internal mould of large cranidium, × 5.   In 36908.

Figs 4, 5, 8.   Cranidium with exoskeleton, incomplete over posterior part of glabella.   Dorsal and oblique lateral views, × 10 ;   Fig. 8, detail of right side to show fine granulation, × 20. In 36909b.   Same rock fragment as cranidium, Fig. 2.

Koldiniella mitella Sivov 1955 (p. 333)

Mila Formation, near Sanghabad, Alborz Mountains

Figs 6, 7.   Well-preserved cranidium in palpebral and right lateral views, × 8.   It 14021.

Figs 9, 10.   Pygidium, dorsal and posterior views, × 10, showing terrace lines confined to border. It 13477.

Fig. 15.   Pygidium, relatively longer than previous specimen, × 10.   It 14022.

Fig. 16.   Hypostome tentatively assigned to this species, ventral view, × 10.   It 13506.

Figs 13, 14.   Small cranidium, possibly a small growth stage of *Koldiniella mitella* but may be referable to *Parakoldinia* (see text, p. 333), × 10.   It 13476.

Tsinania ? sp. (p. 334)

Mila Formation, near Sanghabad, Alborz Mountains

Figs 11, 12.   Incomplete cranidium, exfoliated, anterior and approximate palpebral views, × 10.   It 13493.

Figs 17–19.   Small cranidium, retaining exoskeleton, anterior and lateral views, × 7 ;   Fig. 19, palpebral view, × 10.   It 13458.

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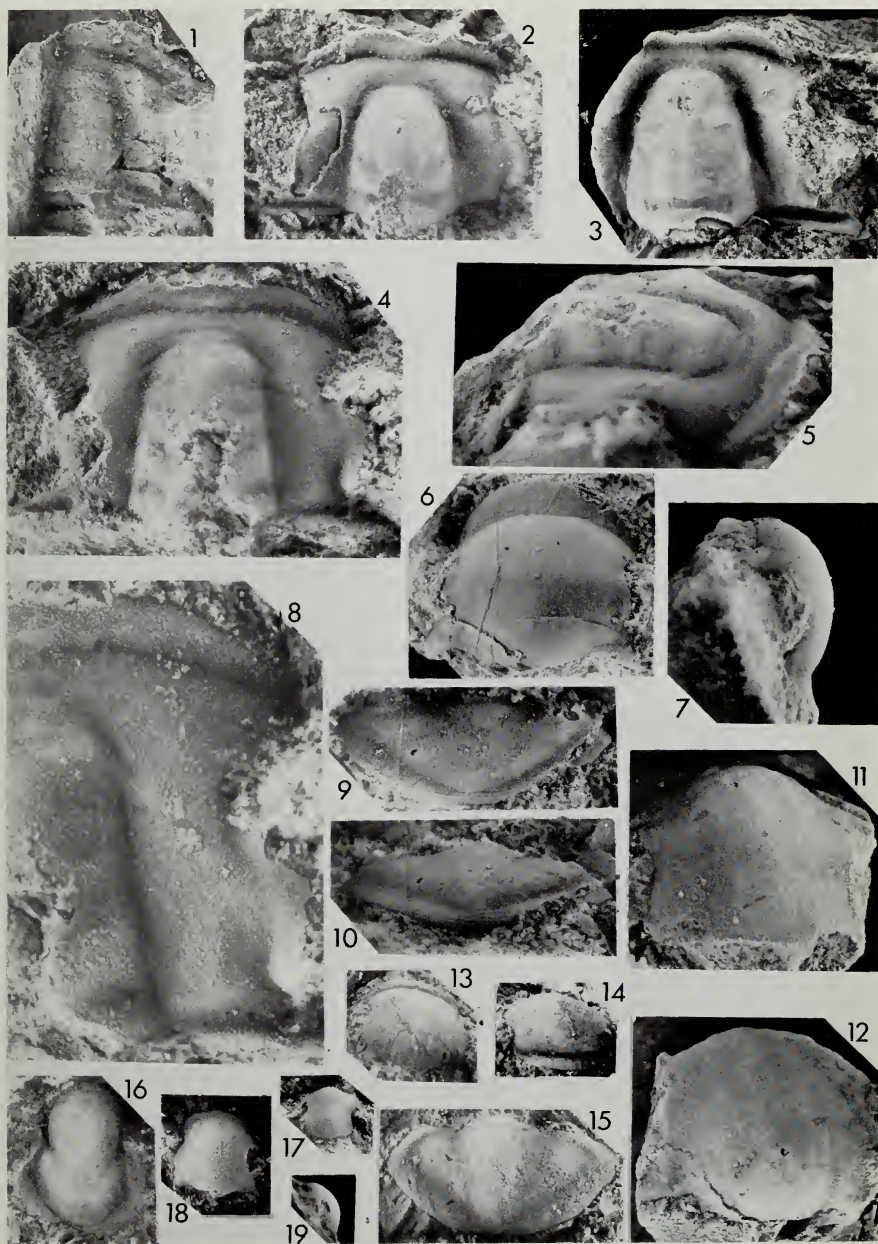
PLATE 10

Dorypyge sp. (p. 327)

Mila Formation, near Sanghabad, Alborz Mountains

FIGS 1, 2.   Pygidium retaining most of exoskeleton, dorsal and oblique lateral views, × 6.
Note impression of part of doublure posteriorly and thin subsidiary spine below third 'main'
marginal spine on left.   It 13461.

Hadragnostus edax sp. nov. (p. 324)

Mila Formation, near Sanghabad, Alborz Mountains

FIG. 3.   Cephalon, glabella broken, × 10.   It 13468.

FIGS 4-6.   Pygidium, tectonically shortened, dorsal, posterior and left lateral views, × 10.
Note terminal node (Fig. 5).   It 13472.

FIGS 7, 8, 12.   Holotype pygidium, dorsal, posterior and left lateral views, × 10.   Note articu-
lating half-ring.   It 13463.

FIGS 9, 10.   Cephalon cut by joints, dorsal and lateral views, × 10.   It 13483a, on same block
as Figs 14, 15.

FIG. 11.   Cephalon, showing rounded glabellar rear, × 10.   It 14023.

FIG. 13.   Small pygidium, × 20.   It 13471.

FIGS 14, 15.   Cephalon, glabella damaged, dorsal and posterior views, × 15.   Note faint node
at posterior end of glabella.   It 13483b, on same block as Figs 9, 10.
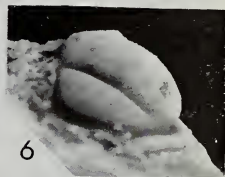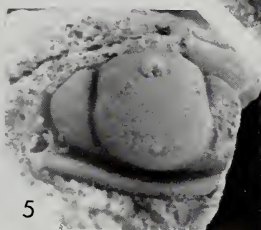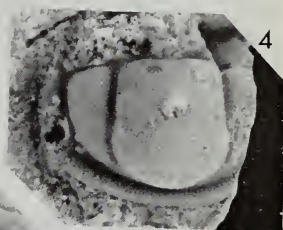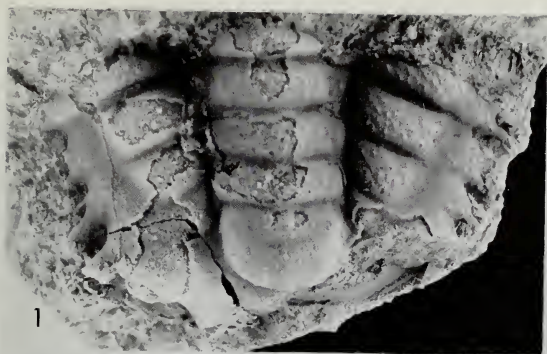
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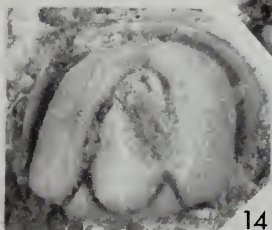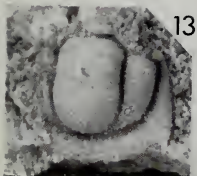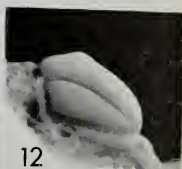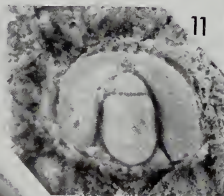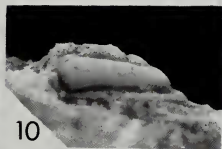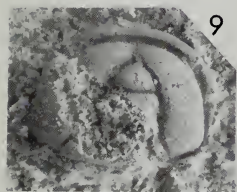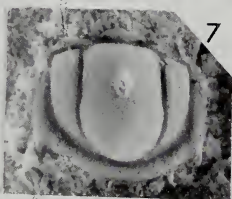
PLATE 11

Peronopsis fallax (Linnarsson 1869) aff. ***minor*** (Brögger 1878) (p. 326)

Mila Formation, near Sanghabad, Alborz Mountains

FIGS 1, 2. Large cephalon, latex cast of external mould, dorsal and lateral views, × 10. Note narrow axial furrow. It 13480b, on same block as Fig. 14.

FIGS 3, 4. Cephalon, slightly compressed laterally, exfoliated in region of axial furrow which appears wide, dorsal and lateral views, × 10. It 13480c.

FIGS 5, 8. Pygidium retaining exoskeleton, slightly deformed obliquely, dorsal and lateral views, × 10. It 13485.

FIG. 6. Large pygidium, partly exfoliated, × 10. It 13467.

FIG. 7. Pygidium, × 10. It 14025.

FIGS 9, 11. Cephalon, laterally compressed, exfoliated in region of axial furrow, lateral and dorsal views, × 10. Note elongate glabellar node and preglabellar depression. It 14024.

FIG. 10. Small cephalon exfoliated in region of axial furrow, × 10. Note preglabellar depression. It 14026.

FIGS 12, 13. Pygidium, longitudinally compressed and partly exfoliated, dorsal and lateral views, × 10. It 13469.

FIG. 14. Cephalon retaining exoskeleton, showing *Ptychagnostus*-like basal lobes, × 10. It 13480d, on same block as Figs 1, 2.

Peronopsis fallax (Linnarsson 1869) cf. ***minor*** (Brögger 1878) (p. 327)

Mancetter Grits and Shales, Merevale No. 3. Borehole, near Nuneaton, Warwickshire, England

FIG. 15. Damaged internal mould, × 10. Institute of Geological Sciences, BDA 1781.

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PLATE 12